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(54) Photodetector system with controllable position-dependent sensitivity.

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DE-A- 2 440 168
DE-B- 2 327 837
GB-A- 2 192 709

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Description

The invention relates to a photodetector arrangement in accordance with the opening part of claim 1.

There is available in the prior art a large variety of systems for producing electrical signals having information content responsive to the orientation of a light source, such as the sun, relative to a photodetector. Most of the known arrangements for performing this function are complex and expensive, and also are rather bulky with their associated electronic signal analysis systems. One known arrangement utilizes a pair of solar cells arranged orthogonal to one another. The incident electromagnetic radiation, or sunlight, causes the solar detectors to generate respective output electrical signals having amplitudes responsive to the angle of incidence of the light. Ratio detecting circuitry is used to determine the angle of incidence with respect to the orientation of the solar detectors, by monitoring and comparing the output signals of the respective solar detectors.

A further known system for determining the direction of incident radiation utilizes a sensor head having a hemispherical convex surface area on which are terminated a plurality of optical fibers. The optical fibers are bundled and terminated at their distal ends with detectors, which are arrayed illustratively in the form of a matrix. This known system, however, in addition to requiring a multiplicity of detectors arranged in a matrix, also requires complex mathematical and evaluation circuitry which render this known system unsuitable in applications where simplicity and economy are required.

A photodetector arrangement according to the opening part of claim 1 is described in GB-A-2 192 709. At least two photodetector elements are housed in a case portion according to which the photodetector elements are encapsulated in a light-transmitting body of resin while the housing comprises a front lens in order to provide different optical characteristics such as viewing angles for each photodetector element. This arrangement is used for measuring different ilumination criteria e.g. circumferencial ilumination and forward ilumination in a system for automatically energizing the headlamps of an automobile.

Other photodetector arrangements as described in DE-B2-2 327 837 and DE-A-2 440 168 use revolving parts in order to measure inpinging light from the sun. In this connection it is already known to cover the system by an optically transparent shield of e.g. glass.

The invention is characterized in claim 1. Preferred embodiments are claimed in claims 2 - 11.

The invention is preferably used for producing a control signal controlling a cooling (or heating) system. This is in particular important in mobile systems.

Particularly in mobile systems which continually are changing their orientation with respect to the sun, it is desirable to modify the output of associated heating and cooling systems so as to take into consideration the effects of sunlight.

The present invention does not require much space for a complex, multi-component sensor and associated computation circuitry. The inventional arrangement is compact, reliable simple and inexpensive. Moreover, it is sufficient to use just one photodetector to monitor the position of a light source, e.g. the sun. The invention provides a system for monitoring the position of a light source wherein an output electrical signal is responsive to an angle of elevation of the light source within respect to a predetermined horizon and for azimuth.

The invention is particularly suited for mobile applications.

Embodiments of the invention can control the cooling/heating or air-conditioning systems of a vehicle. The source of light of interest is the sun. In view of the heat generated by the sunlight the cooling capacity if the air-conditioner is controlled in response to the angle of incidence of the sunlight.

In accordance with the invention the photodetector comprises an input for receiving the input light. The light modulator is preferably arranged in the vicinity of the input and determines a position-responsive sensitivity characteristic of the photodetector system. The diffuser is advantageously installed optically intermediate of the photodetector and the light modulator. The diffuser serves to scatter the light impinging upon the photodetector and thereby diminish the effect of position-dependent characteristics of the light-sensitive area of the photodetector. More specifically, most photodetectors have light sensitive areas called photocathodes which ideally should be uniformly sensitive to light. However, photocathodes have a sensitivity to light which is a function of the location on the photocathode which is being illuminated. Thus, when a light beam moves across a typical photocathode, the output electrical signal from the photodetector varies, not because the intensity of the incident light beam changes, but rather because the light beam moves across portions of photocathode with different sensitivities to light. The diffuser, since it is arranged to cover the photodetector, diminishes the position-dependent characteristic of the photocathode of the photodetector by scattering the light and averaging the error out substantially over the entire surface.

In accordance with a specific illustrative embodiment of the invention, the light modulator is configured in the form of a shroud which is installed over the diffuser to occlude all but a predetermined portion of the input of the photodetector. In this manner, only light which is propagated over a predetermined range of angles of incidence is permitted to impinge upon the diffuser, and therefore the output electrical signal of the photodetector is responsive to light which is received at an angle of incidence which is within this predetermined range.

In other embodiments of the invention, the light modulator is formed of one or more markings which are applied directly to the diffuser, illustratively by printing. In addition to a pattern of marks which absorbs all light incident upon the device, a pattern of marks, such as a very fine dot pattern, may be used to control partial transmission of the incident light, in a manner analogous to the production of half-tones in printed media.

In accordance with a further specific illustrative embodiment of the invention a cooling system control element, which may be used to control the output of the air-conditioner of a vehicle, is mounted at a location on the vehicle which is subjected to sunlight, and at a predetermined orientation with respect to the vehicle. A photodetector, as described hereinabove, has associated therewith a light modulator which controls the magnitude of the sunlight which is incident upon the input of the photodetector.

In certain embodiments of this cooling system control element aspect of the invention, the light modulator blocks the sunlight from reaching the input of the photodetector, except over a predetermined range of angles of incidence. The predetermined range of angles of incidence may include predetermined angles of elevation and angles of azimuth. In addition, the light modulator need not block the sunlight totally, but may merely impede same whereby partial transmission of the sunlight is permitted. Thus, the present invention is not limited to transmissive and non transmissive ranges of angles of incidence, but may also include partial transmission.

There are a number of issues which should be taken into consideration when designing a solar sensor for an automobile so that it will achieve the desired response function to the sunlight as a function of the elevation and azimuth of the sun. The central idea in the modeling is to determine the effectiveness with which the sun heats the passenger compartment of an automobile as a function of its position in the sky relative to the automobile. The solar sensor should be less responsive to sunlight for those solar angles where some part of the automobile is interfering with the passage of sunlight into the vehicle. More specifically, the solar sensor should be less responsive when the sun is directly overhead because the roof of the automobile shields the passenger compartment. On the other hand, when the sun is shining directly into the windshield, the solar sensor should be more responsive.

An illustrative solar sensor embodiment of the invention has three basic elements: an absorber and light modulator respectively, which could be in the form of a shroud, a diffuser, and a photodetector. One approach to designing such a solar sensor takes employs a hemispherically shaped diffuser. This shape is set forth herein for convenience in the following analysis, but it is understood that numerous other shapes can be employed without departing from the scope of the claimed invention. With the diffuser installed on the dashboard of a vehicle, as viewed from above, the diffuser appears as a circle, i.e., the projection of the diffuser is a circle. However, when viewed from the side (horizon), it appears as a semicircle.

It is the total amount of light which strikes a diffuser that determines the output signal from the photodetector. In other words, since it is the projection of the diffuser along the direction of the sunlight which is important, the sun directly overhead strikes twice the area of the diffuser generating twice the response as when the sun is on the horizon.

When considering the shape of the absorber, shroud or light modulator which is to be installed over the diffuser, it is important to consider and determine its distance from the diffuser for each position of the sun. Consideration is then given to the intersection of each ray of sunlight incident on the diffuser. Either by having some number of rays strike a shroud, or equivalently, having some fraction of the rays absorbed by an absorber, it is within the capabilities of persons of ordinary skill in the art, in view of the teaching herein, to design the shroud or absorber or light modulator to obtain the desired angular response function. The final design must be found in an iterative way because the existence of a shroud or absorber affects the number of rays that will be absorbed at more than one solar angle.

The method, or approach, described immediately hereinabove for designing a solar detector produces surprisingly excellent flexibility. In fact for a diffuser which is small compared to the size of the absorber or light modulator or shroud, for a single position of the sun, the path that the sunlight which strikes the diffuser takes through the absorber, or that is incident on the shroud, only strikes a small element of the absorber or shroud. Thus, in this situation, each element of the shroud or absorber is independent of all other elements

and the design is particularly simple since it requires no iteration. Each element of said light modulator or absorber or shroud corresponds to a single position of the sun.

Comprehension of the invention is facilitated by reading the following detailed description, in conjunction with the annexed drawing, in which:

Fig. 1 is an isometric representation of a specific illustrative embodiment of the invention which employs a shroud for defining a range of angles of incident light which can impinge upon the photodetector;

Fig. 2 is an isometric representation of a specific illustrative embodiment of the invention which employs a printed pattern on the diffuser element for defining a range of angles of incident light which can impinge upon the photodetector, and additionally a region of partial transmissivity of the light; and

Fig. 3 is a cross-sectional representation of an embodiment of the invention wherein modulation of the impinging light is achieved as a function of the thickness of the light modulator.

Fig. 1 is an isometric representation of an embodiment of the invention wherein a photodetector system 10 is shown to have a diffuser element 11 which is installed in a light modulator or shroud 12. In this embodiment, the shroud is formed integrally with a substantially cylindrical body 13 which has ears 15 extending therefrom for assisting in mounting and installation of the photodetector system 10 onto a vehicle (not shown). In this specific embodiment, body 13 is affixed to a base number 17 which also facilitates mounting and installation.

As shown in this figure, the shroud 12 is configured to have a top portion 20 which is configured to overlie the diffuser element 11. In this specific embodiment, the top portion 20 has an extension 21 which prevents light from the light source (not shown) directly over the photodetector system 10 from impinging upon the diffuser element 11. In this manner, the shroud 12 with its respective side and top portions and extensions thereof defines a region through which the diffuser element 11 can be exposed to light. The region of exposure can be defined in terms of a range of angles of elevation and a range of angles of azimuth.

Fig. 2 is an isometric representation of a specific illustrative embodiment of the invention wherein elements of structure having analogous correspondence to those of Figure 1 are similarly designated. In Fig. 2, the diffuser element 11 is not covered by a shroud, as discussed hereinabove with respect to Fig. 1, but rather has printed thereon markings which define regions of desired exposure. More specifically, the diffuser 11 in this specific embodiment has printed thereon opaque markings 30 over a predetermined region thereof which occlude the diffuser 11 from any impinging light. The particular configuration of opaque markings 30 on the diffuser element 11 can be adjusted by persons of skill in the art to meet necessary criteria.

The diffuser element 11 is shown to have in Fig. 2 a further region of markings 32 which form a partially opaque region. Partially opaque region may be formed by printing on the diffuser 11 a multiplicity of very fine dots in a pattern analogous to conventional half-tone printing. Persons of skill in the art can configure the dot density to achieve a desired level of light transmissivity.

Fig. 3 is a cross-sectional schematic representation of a light modulator as an absorber cap 40 which is arranged to overlie a photodetector 41. As shown in this figure, the photodetector 41 receives an illumination which is generally designated by arrow 42 from a light source 43. The Absorber cap 40 may be formed of a translucent, and preferably transparent, material which has a coloration added, such as a dye, whereby the amount of light which is transmitted there through is a function of the thickness of the cap 40. For purposes of the present discussion, the light source 43 is assumed to be collimated, and may be the sun.

The path that the light radiation incident upon photodetector 41 takes through the walls of the absorber cap 40 is illustrated by shaded area 45. Assuming a hemispherical absorber cap, the amount of light which reaches photodetector 41 can be correlated to the angle ϕ. Thus the electrical signal which is produced at output leads 47 of the photodetector 41 is responsive to this angle.

It is to be understood that the outer and/or inner surfaces of the absorber cap 40 may be provided with printed markings or sprayed-on coating which achieves a desired transmission pattern therethrough. Moreover, persons of skill in the art can design the absorber cap 40 and its associated variations in thickness to achieve a desired function, and also include within the design compensation for other effects, such as refraction.

Claims

1. Photodetector arrangement (10) for producing an electrical output signal responsive to the position of a light source (43) with respect to the arrangement, comprising
   - a photodetector (41) for outputting an electrical signal responsive to the amount of light incident on the photodetector (41);
   - light modulating means (12; 30, 32) for modulating the amount of light incident on the photodetector (41) depending on

the position of the light source (43) with respect to the photodetector (41);
characterized in that
- light diffusing means (11; 40) is disposed intermediate said photodetector (41) and said light modulating means for diffusing light incident thereon.

2. Arrangement as claimed in claim 1, **characterized in that** said diffusor (11, 40) is installed optically intermediate of said photodetector (41) and said light modulator (12; 30; 32).

3. Arrangement as claimed in claim 1 or 2, **characterized in that** the amount of light transmittance of said diffusor (40) as a function of the thickness of said diffusor (40).

4. Arrangement as claimed in claim 3, **characterized in that** said diffusor (40) comprises a substantially transparent cap member arranged to overlie said photodetector (41), said cap member having a light absorptive coloration therein, and having a thickness which varies over predetermined portions thereof for producing a position-responsive characteristic of the photodetector arrangement (10).

5. Arrangement as claimed in one of the preceding claims, **characterized in that** said light modulator comprises coatings (30 32) applied to said diffusor (11) for occluding all but said predetermined portion of said input of said photodetector (41).

6. Arrangement as claimed in claim 5, **characterized in that** said coating (30) comprises a first portion for preventing transmission of said light from the source (43) of light to the input of said photodetector (41).

7. Arrangement as claimed in one of the preceding claims, **characterized in that** said light modulator comprises a shroud (12) installed for occluding all but a predetermined portion of said input of said photodetector (41).

8. Arrangement as claimed in one of the preceding claims, **characterized in that** said diffusor (11; 40) is hemispherically shaped.

9. Arrangement as claimed in one of the preceding claims, **characterized in that** said light modulator comprises sunlight blocking means for preventing the incidence or the sunlight upon said input of said photodetector (11) except over a predetermined range of angles (ϕ) of incidence.

10. Arrangement as claimed in claim 9 wherein said predetermined range of angles (ϕ) of incidence of the sunlight include a predetermined range of angles of elevation.

11. Arrangement as claimed in claim 9 wherein said predetermined range of angles (ϕ) of incidence of the sunlight include a predetermined range of angles of azimuth.

12. Use of an arrangement as claimed in one of the preceding claims for producing a control signal controlling a cooling system.

Patentansprüche

1. Fotodetektorsystem zum Erzeugen eines elektrischen Ausgangssignals in Abhängigkeit von der Position einer Lichtquelle (43) in Bezug auf das System, das einen Fotodetektor (41) für die Ausgabe des elektrischen Signals in Abhängigkeit vom Betrag der auf den Fotodetektor (41) einfallenden Lichtmenge und ein Lichtmoduliersystem (Lichtmodulator) (12; 30, 32) zum Modulieren der auf den Fotodetektor (41) einfallenden Lichtmenge in Abhängigkeit von der Position der Lichtquelle (43) in Bezug auf den Fotodetektor (41) aufweist,
dadurch gekennzeichnet,
daß ein Lichtdiffusor (11; 40) zwischen dem Fotodetektor (41) und dem Lichtmodulator (12; 30, 32) zum diffusen Ausbreiten bzw. Zerstreuen des dort einfallenden Lichts angeordnet ist.

2. System nach Anspruch 1, **dadurch gekennzeichnet,** daß der Diffusor (11; 40) optisch zwischen dem Fotodetektor (41) und dem Lichtmodulator (12; 30, 32) installiert ist.

3. System nach Anspruch 1 oder 2, **dadurch gekennzeichnet,** daß die Menge der Lichtübertragung des Diffusors (40) eine Funktion der Dicke desselben bildet.

4. System nach Anspruch 3, **dadurch gekennzeichnet,** daß der Diffusor (40) eine im wesentlichen

transparente Kappe aufweist, welche den Fotodetektor (41) überdeckt, und daß die Kappe eine lichtabsorbierende Kolorierung und eine Dicke aufweist, welche in vorbestimmten Teilen derselben variiert, um eine positionsabhängige Charakteristik der Fotodetektoreinrichtung zu erzeugen.

5. System nach einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
daß der Lichtmodulator Überzüge (30, 32) aufweist, welche am Diffusor (11) angebracht sind, um beinahe alle außer den vorbestimmten Teilen des Eingangs des Fotodetektors (41) zu okkludieren.

6. System nach Anspruch 5,
dadurch gekennzeichnet,
daß der Überzug (30) einen ersten Teil aufweist, der die Lichtübertragung von der Lichtquelle (43) zum Eingang des Fotodetektors (41) verhindert.

7. System nach einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
daß der Lichtmodulator eine Abdeckung (12) aufweist, die derart installiert ist, daß mit Ausnahme des vorbestimmten Teils des Eingangs des Fotodetektors (41) beinahe alle Teile okkludiert werden.

8. System nach einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
daß der Diffusor (11; 40) halbkugelartig ausgebildet ist.

9. System nach einem der vorhergehenden Ansprüche,
dadurch gekennzeichnet,
daß der Lichtmodulator eine Sonnenlichtsperreinrichtung zum Verhindern des Einfalls von Sonnenlicht auf den Eingang des Fotodetektors (11) mit Ausnahme eines vorbestimmten Bereichs des Einfallwinkels (ϕ) aufweist.

10. System nach Anspruch 9,
dadurch gekennzeichnet,
daß der vorbestimmte Bereich des Einfallwinkels (ϕ) des Sonnenlichts einen vorbestimmten Bereich des Höhenwinkels einschließt.

11. System nach Anspruch 9,
dadurch gekennzeichnet,
daß der vorbestimmte Bereich des Einfallwinkels (ϕ) des Sonnenlichts einen vorbestimmten Bereich von Azimuthwinkeln aufweist.

12. Verwendung des Systems nach einem der vorhergehenden Ansprüche zur Erzeugung eines Steuersignals, das ein Kühlsystem steuert.

Revendications

1. Système de photo-détecteur (10) à engendrer un signal de sortie électrique en réponse à la position d'une source lumineuse (43) par rapport au système, comprenant
   - un photo-détecteur (41) à sortir un signal électrique en réponse à la lumination de la lumière incidente sur ledit photo-détecteur (41);
   - des moyens modulateurs de lumière (12; 30, 32) pour moduler la lumination de la lumière incidente sur ledit photo-détecteur (41) en fonction de la position de ladite source lumineuse (43) par rapport audit photo-détecteur (41);

   caractérisé en ce que
   - des moyens de diffusion de lumière (11; 40) sont disposés à un point intermédiaire entre ledit photo-détecteur (41) et lesdits moyens modulateurs pour diffuser de la lumière y incidente.

2. Système selon la revendication 1,
caractérisé en ce que
lesdits moyens diffuseur (11; 40) sont installés à un point optiquement intermédiaire entre ledit photo-détecteur (41) et lesdits moyens modulateurs (12; 30; 32).

3. Système selon la revendication 1 ou 2,
caractérisé en ce que
la lumination de la transmission de lumière desdits moyens diffuseur (40) est en fonction de l'épaisseur dudit diffuseur (40).

4. Système selon la revendication 3,
caractérisé en ce que
ledit diffuseur (40) comprend un élément capot essentiellement transparent qui est disposé à coiffer ledit photo-détecteur (41) et qui contient une teinture absorbante la lumière et a une épaisseur qui varie sur ses parties prédéterminées afin d'engendrer une caractéristique en réponse à la position dudit système photo-détecteur (10).

5. Système selon une quelconque des revendications précédentes,
caractérisé en ce que
ledit modulateur de lumière comprend des enductions (30, 32) appliquées audit diffuseur

pour l'occlusion de toute l'entrée dans ledit photo-détecteur (41) sauf ladite partie prédéterminée.

6. Système selon la revendication 5, **caractérisé en ce que** ladite enduction (32) comprend une première partie à empêcher la transmission de la lumière, qui provient de ladite source lumineuse (43), à l'entrée dudit photo-détecteur (41).

7. Système selon une quelconque des revendications précédentes, **caractérisé en ce que** ledit modulateur de lumière comprend une enveloppe (12) montée pour l'occlusion de toute l'entrée dans ledit photo-détecteur (41) sauf ladite partie prédéterminée.

8. Système selon une quelconque des revendications précédentes, **caractérisé en ce que** ledit diffuseur (11; 40) a une forme hémisphérique.

9. Système selon une quelconque des revendications précédentes, **caractérisé en ce que** ledit modulateur de lumière comprend des moyens de blocage de la lumière solaire pour empêcher l'incidence de la lumière solaire sur ladite entrée dudit photo-détecteur (11) sauf sur une plage prédéterminée des angles (ϕ) d'incidence.

10. Système selon la revendication 9, dans lequel ladite plage prédéterminée des angles (ϕ) d'incidence de la lumière solaire comprend une plage prédéterminée des angles d'élévation.

11. Système selon la revendication 9, dans lequel ladite plage prédéterminée des angles (ϕ) de la lumière solaire comprend une plage prédéterminée des angles azimutaux.

12. Emploi d'un système selon une quelconque des revendications précédentes, à engendrer un signal de commande pour commander un système de réfrigération.

FIG. 1

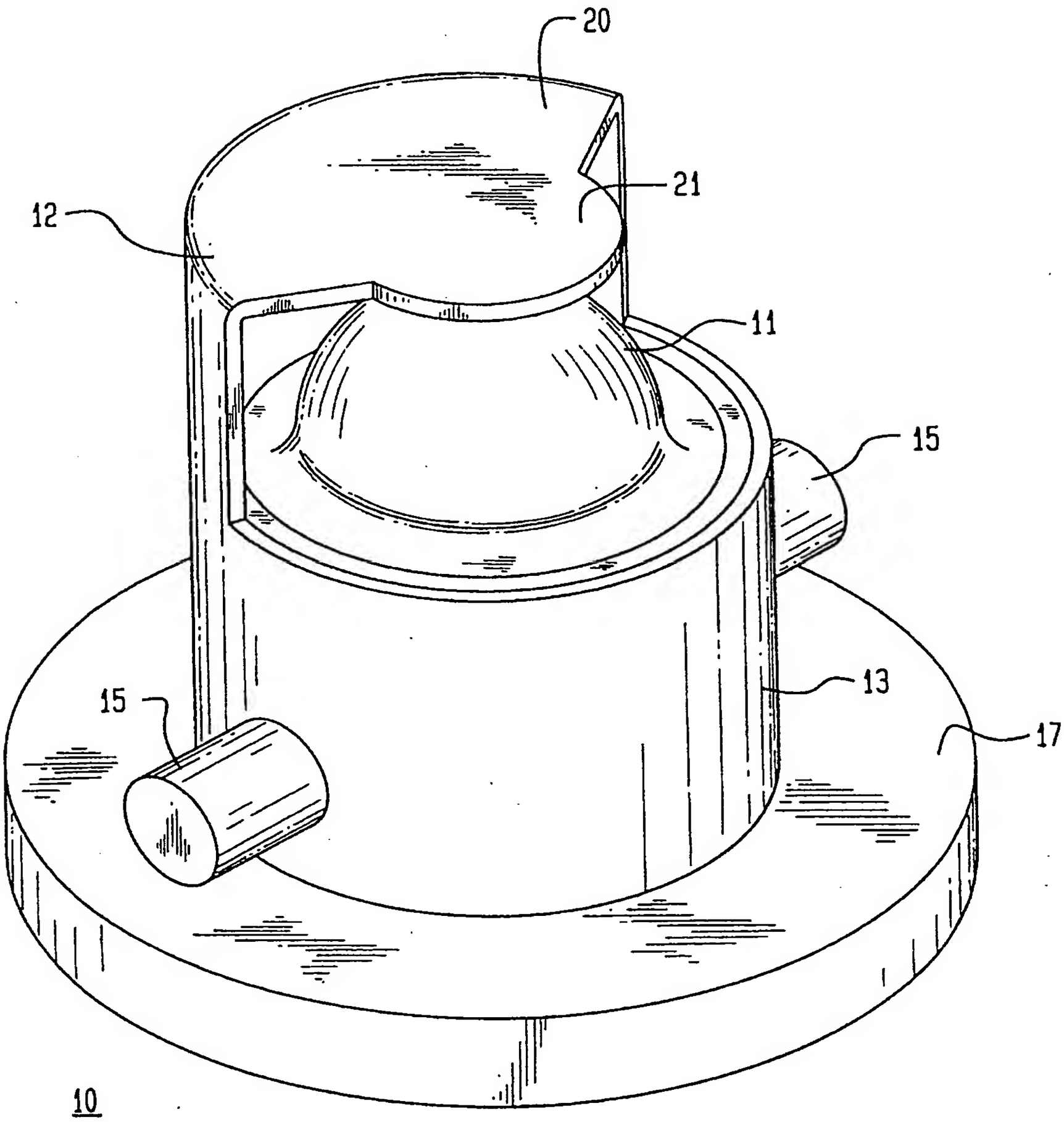

FIG. 2

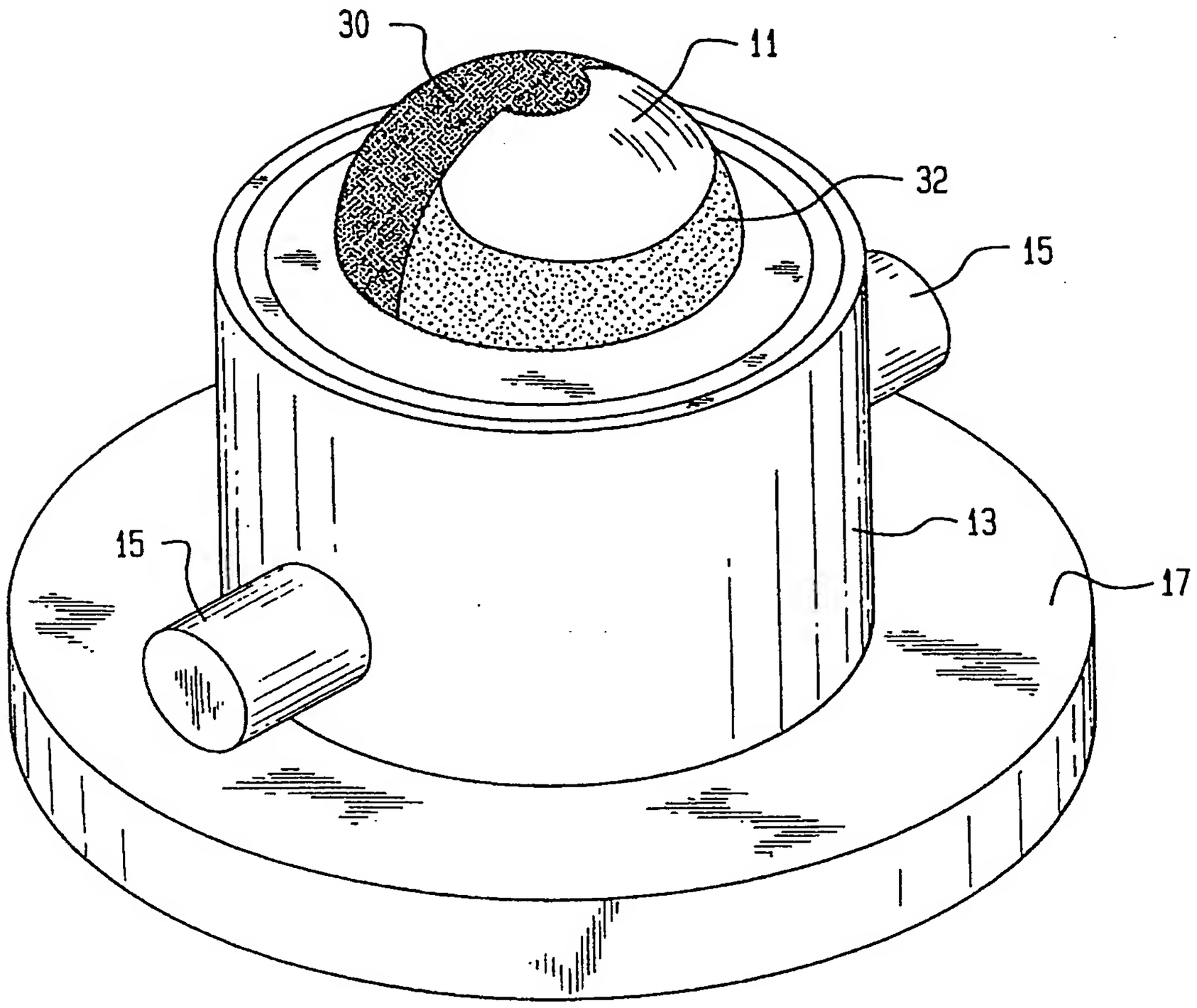

FIG. 3